

Diabetics' Self-Management Systems: Drawbacks and Potential Enhancements

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ABSTRACT

Diabetes is a pandemic that is growing globally, and by the year 2030 it is expected to effect three people every 10 minutes. In the UK, it is estimated that by 2025, 5 million people will have diabetes. Diabetes is currently costing the British National Health Service (NHS) over £1.5m an hour. This equates to 10% of the NHS budget for England and Wales or over £25,000 being spent on diabetes every minute. It is important to minimise these costs by employing new techniques to curtail existing cases and limit new cases. This goal will be accomplished through patient education and self-management. Self-management and self-monitoring play a significant role in restraining diabetes complications. A major component of self-management involves regular blood testing and detailed record keeping through comparative analysis, extensive surveying of diabetic's patients and medical professionals were carried out.

The outcome of this research was used to determine how to best create a global and easily accessible diabetes management e-toolkit, that will help the diabetic community alongside the medical community to reduce the harmful effects of this disease. The e-toolkit, that has been formed successfully, can connect the patient to their doctor. It will provide the patient with a single means of recording every important vital health factor and simultaneously allowing the doctor to access real-time monitoring.

The e-toolkit proposed in this paper would facilitate in bringing both the medical and diabetic group of people closer together resulting in a strengthened relationship. Patients will be able to record each imperative health factor whilst having the ability to communicate with their doctor and in turn, effectively managing their diabetes to their utmost potential.

Keywords

Diabetes, British National Health Service, E-toolkit, Doctor, Patient

1. INTRODUCTION

Diabetes is a long-lasting health disorder which distresses people of all ages, race and economic classes. If not treated, the effects may be fatal, involving long-term harm to vital organs. Usually, diabetes is a lasting health disorder, medicinal specialists concur that it requires close supervision, observation and intense self-organisation (American Diabetes Association, 2018).

The global healthcare expenditure on people with diabetes was estimated to be USD 850 billion (£651 billion) in 2017 (N. H. Cho, 2018). As these numbers race out of control, the medical community struggles to keep up with the demand for care and societies around the world attempt to adjust to this 'catastrophic' pandemic (webmd.com, 2019). On the 8th November 2018, according to the National Diabetes Audit Report, diabetes

prescriptions now cost NHS £1bn (National Diabetes Audit Report, 2017).

Diabetic patients play a big role in controlling the disease, with self-management by ensuring that regular measurements of their blood glucose levels are recorded after waking up, before a meal and after a meal, before and after an exercise, before going to bed, and at other occasions, if and when required (Alan J. Sinclair and Simon C.M. Croxson, 2009). Consequently, doctors are frustrated in their treatment of diabetic patients and find it difficult to adjust medications and other factors when patients are unable to express how various influences affect their condition (Larne AC1, 1998). When doctors don't get the information, they require in a timely manner, this places diabetic patients at a much higher risk of developing complications.

To this end, this research has utilised the ever-increasing use of personal computers and mobile smart phones to develop a newer and better e-toolkit for diabetics to monitor and record their health risk factors. (Darwish F, 2012). The existing diabetes monitoring tools and applications were created by blood glucose or insulin pump manufactures. Therefore, these applications are almost always created from a commercial vantage, and not necessarily with either the patient's or the medical community's best interests in mind hence they are often lacking in their effectiveness and applicability. Thus, this research has proposed an e-toolkit which overcomes the limitations of the existing applications.

2. LITERATURE REVIEW

This section discusses in detail the existing diabetes monitoring systems in the market. It highlights their limitations from the perspectives of diabetic patients and the concerned medical staff.

2.1 Diabetes UK App



This application enables diabetics to track something beyond blood glucose and insulin readings. It can record calories, carbohydrates, body weight and ketones. The recorded information can then be transferred into

graphs to illustrate the data in a visual format (Diabetes UK, 2018). However, the ability to send patient data to medical professionals is not available and therefore this restricts the communication of readings between the patient and their doctor (NHS Croydon Clinical Commissioning Grp, 2018). They would need to print the data which adds further steps and equipment resulting in an impact on the environment as paper wastage is involved. Since the lack of funding from the charity Diabetes UK,

the app is no longer used by many patients and therefore has been discontinued on the IOS software.

2.2 Accu-Chek



Accu-Chek Smart Pix system is a product by Roche Diabetes Care based in the United Kingdom, the most famous, global producer of diabetic equipment (accu-chek.co.uk, 2019). The system is efficient and has an interface that records blood glucose and insulin levels directly from the insulin pump made only by Accu-Chek. The data is

then generated on to the user's PC, which is then filtered automatically and accordingly, reducing any human error.

The drawbacks of this system are the need for other equipment like a laptop or PC and a specific software to upload the data to be converted into relevant information. This is restrictive as not all patients, such as the elderly or low-income class, have accessibility to this equipment and they may also struggle to set the system up. Also, the system can be quite costly depending on where you are residing, as in the UK it is priced at £49.99. (amazon.co.uk, 2019). However, in the US the same system is priced at a much higher price of \$148. (glucosemeters4u.com, 2019).

Finally, the system may be enough for a simple glucose reading to inform the patient to help them keep track however, the system has no capability to inform or transfer this data to medical professionals through a portal or even by email (accu-chek.co.uk, 2019). Therefore, the only option is to print the data and take it on appointments, which again is limits the efficiency and accuracy.

2.3 One Touch



OneTouch (formerly known as LifeScan) is a mobile/smart phone application made by a division of JNJ, a well-known pharmaceutical company in America (myonetouch.co.uk,

2019). The app is readily available on the IOS platform and can link directly with blood glucose meters through Bluetooth or an iPhone cable linking to a laptop/PC. However, this is not directed to the entire population as this is only available to IOS users and is not accessible by other popular operating systems such as Android. A major downside to this app was a recall in 2013 caused by readings of high blood glucose levels of 1024mg/dl or above causing the device to shut off. Therefore, this app was not reliable and effective for diabetics. This caused a lack in trust in the company, monetary losses and major time delays.

2.4 Glooko Diasend



The Diasend System depends on a device, called a 'transmitter', which the patient must physically connect to their PC. This transmitter is intended to automatically detect and import readings from various glucose meters

and insulin pumps to the server. The information can then be expanded into a chart format in order to provide visual

illustrations of the collected data. The information that is uploaded on to the system can be accessed from anywhere. However, in order to transfer the data to the server, a large transmitter is needed for this transmission, which is rather bulky and heavy. This constrains usability as the requirements for a laptop/ PC and a transmitter is restrictive. Moreover, the data can only be transferred through cables as there is no Bluetooth network which again impedes the usage of the system. Another problem is that this system can only be used by a patient who has been assigned through a referral system from the healthcare professional office. If both the patient and medical professional are enrolled, then the data can be viewed by through the server portal. Overall, this system is costly and requires a subscription which is not clear in terms of whether this is monthly or annually.

2.5 Conclusion of Diabetic Monitoring Devices

Although innovation is continually developing, and there is a continuing exertion being made to make applications and sites of use for the diabetic group. The proof introduced here, demonstrates that it is hard to discover a system that genuinely satisfies the diabetic's requirements. One of the requirements being a solitary place which truly fulfils the diabetic's need for a sole place where all vital data can easily and quickly be recorded. Besides, it is essentially difficult to find any sort of system which gives the medicinal group ongoing access to such information in real time. This goal of this project is to provide patients with the capacity to login and share all their vital data with their medical team, in an organised and effective way.

Equally critical, is the medical professional's ability to give feedback to the patient and mediate in case of a medical complication or emergency. These features will be this web portal main functions.

Below is a table showing the main differences between the above systems and the proposed system:

Systems	Special Hardware Required	Subscription required	Connects to Doctor
Our Proposed e-Tool Kit	No	No	Yes
Diasend	Yes	Yes	No
Diabetes Tracker UK	No	Yes	No
Lifescan	Yes	Yes	No
Accu-Chek	Yes	Yes	No

Table 1– Systems Comparison

3. PROPOSED SOLUTION

The goal of the research study is to create a worldwide available e-toolkit that will overcome the current issues that the existing diabetes monitoring system has and will enable the medical professionals and patients to communicate.

The e-toolkit is expected to be user friendly and accessible to patients allowing them to record data such as individual risk factors, which are important in monitoring their condition. The patient will have a portal that can record consistent and real time readings, which can be accessed from home, work or from any other location desired using a mobile phone. Patients will no longer have to experience the inconvenience of carrying a journal and writing notes. The portal will be accessed by the patient's doctor allowing the vital patient/doctor interaction.

Doctors and patients can interact using the direct messaging system. As the system requires a log in, procedures will be implemented to allow regular monitoring with the aim of the

portal becoming integrated to the patients' daily routine. Additional features can potentially involve: the display of graphs, charts, notifications to high-risk patients as well as enabling data from lab results to be recorded and shared. The e-toolkit will suggest treatments to the doctor according to the readings, which the patients have already input.

3.1 Survey Design, Implementation and Feedback Analysis

This section covers the structure of the conducted survey, the diabetic patients and medical professional feedback as well as the analysis of the collected data. We started by giving a brief introduction about the approach which has been followed to implement the conducted survey. Furthermore, we explained the ethics standards that were agreed upon among all parties, being the diabetic patients, medical professionals and researchers.

3.2 Survey Research Process

The survey information that was gathered will be presented in this order: first, a blank copy of the issued survey (survey development), then a presentation of the results (survey administration) and finally an analysis of those results. This process is explained in Angela M book titled "Survey methods for educators: Analysis and reporting of survey data".

The process is demonstrated in the figure shown below.

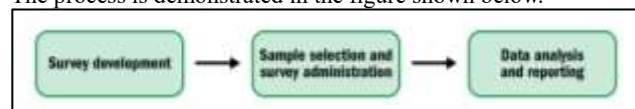


Figure 1 – Survey Process - Source: (Angela M. Pazzaglia, 2016)

3.2.1 Medical Professionals Survey Structure

There were two surveys for this research study, one for the medical healthcare professionals and the other for diabetic patients.

The medical healthcare profession survey had particular questions such as "What do you consider to be the benefits of this proposed system". Also, there was questions with open answers to allow suggestions, for example, "Would you use this application to share information and comments with other health care professionals, if such a feature was available?". This allows the research study to have a variety of answers to the questions,

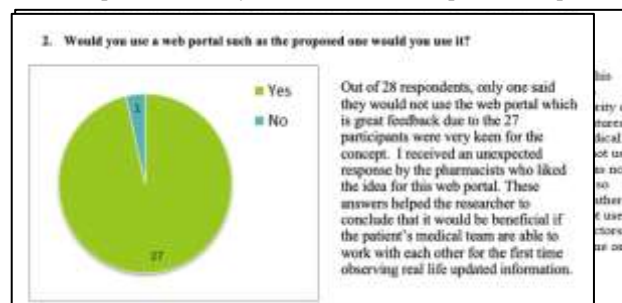
Please pick your medical field:	
Primary Care Physician	Optometrist / Ophthalmologist
Physician's Assistant or Nurse Practitioner	Diabetes Educator
Nurse	Dietician
Endocrinologist	Dentist
Podiatrist	Mental Health Care Provider
Other	
Would you use a web portal such as the proposed one would you use it?	
Yes	No
What would you consider to be the benefits of such a website / system?	
Better ability to monitor patient condition	Ability to securely communicate with patients between appointments
More likelihood that patient will regularly record health information	No email
More likelihood that patient will record the correct information	Ability to easily share patients' information with other health care providers
More likelihood that patient will record information in greater detail	Ability to access patient information from any location (e.g. multiple offices, at home)
Ability to receive alerts as to patient's sudden change in condition (without having to wait for patient's next appointment and worsening of condition)	Shorter, more productive appointments because all info consolidated
Ability to track trends in patients' health	Shorter, more productive appointments because info can be reviewed prior to patient arrival
Ability to see patients' information in graphs and charts	Other

improving the research qualitative data.

Figure 2 – Example of Medical Healthcare Professionals Survey
Figure 3 - Answers to the above survey illustrated as a bar chart

3.2.2 Medical Professionals Survey Results Analysis

The results of the medical healthcare profession survey have been helpful for this research study, as 98% of the healthcare professionals said they would use the proposed e-toolkit and shared enthusiasm about the prospect. Some responders did give suggestions with the questions that had open answers. For example, with question 7 "If a feature were included that allowed your office, or the patients themselves, to input medical test results (for monitoring / trend tracking purposes), would you use/support such a feature?". The overall recommendations to this were that it would be supported if it were restricted to input, from medical personnel only and would be helpful to import the



patient's medical lab results (A1C, cholesterol, etc) so that it can be recorded in one convenient location.

Figure 4 - Example of a question and a corresponding graph showing the results

3.2.3 Diabetic Patients Survey Structure

The diabetic patient survey questions were aimed at their personal health, such as "How long have you had diabetes?" and "Do you find it a hassle to keep track of your readings?". Also, questions aimed about current applications "What features do you dislike about your current system/monitoring e-Toolkit?" and open questions about possible suggestions/recommendations about a system they would use.

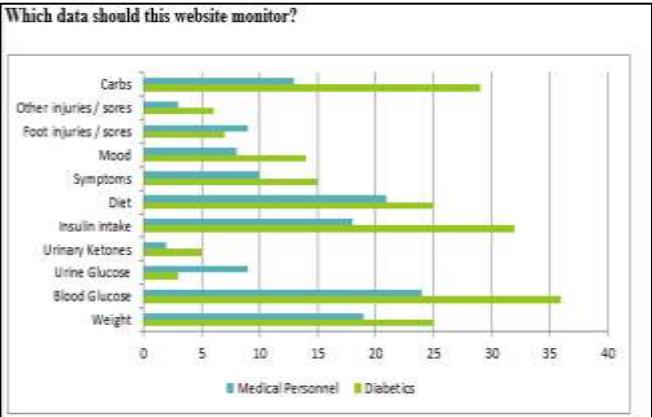
How long have you had diabetes?	
Less than 5 years	5-10 years
10-20 years	20+ years
Do you find it a hassle to keep track of your readings?	
Yes	No
How do you currently track your diabetes information?	
Written (paper) log, journal, or planner	Electronic log, journal, file (e.g. Word, Excel, etc)
Generic website	Generic phone app
Website for your specific monitoring device	Phone app for your specific monitoring device
Other	
Would a website like this appeal to you?	
Yes	No
Maybe	Why or why not?
If an app were available to correspond to the website, would you use it?	
Yes	No
Maybe	Why or why not?
What data would the website monitor?	
Weight	Symptoms
Blood Glucose level	Mood
Urine Glucose level	Foot injuries / sores
Insulin intake	Other injuries / sores
Diet	Carbs
Urine Ketones	

Figure 5 - Example of the diabetic patient survey

3.2.4 Diabetic Patients Survey Results Analysis

The results of the diabetic patient survey showed that 37.5% of the patients had diabetes for more than 20 years. 15 patients (with another 13 that answered "maybe") said they would use the proposed system which links the medical relationship between

patients and professions. This finding is a boost of confidence that diabetics would be interested in this proposed e-toolkit. In the data, we found out that a staggering 65% of the diabetic patients confirmed that it is a hassle to keep track of their own readings. This response emphasised on a point that there are two classes of diabetics; those who take the condition seriously and stay on top of their health with exercise and diet. Then there are those who disregard most medical advice, continue to have a lifestyle as they did before their diagnosis, showing not much care for their health. The second type of diabetics are the ones who will most likely not want to participate in such a survey or use the suggested application. From these survey results, there are some side-by-side comparisons from the same questions to show the similarities or differences in the results. The question below is the most important analysis of the question, “which data should this e-toolkit monitor?”.



This comparison shows doctors and patients agreed which health factors should be recorded. Both parties also decided the importance and priority of this documentation. Each group indicated the same fields for their top six: weight, blood glucose, insulin intake, diet, carbohydrate consumption and symptoms.

Figure 6 – Bar chart showing answers for what the website should monitor

3.2.5 Survey conclusion and analysis

Occasionally, whilst doing a research study like this one proposed, some aspects may be missed like the impact on the people themselves throughout their lives, physically and emotionally. Whilst collecting these findings many astonishing ideas were discovered from the diabetic community. Throughout the depths of the numerous subjects in this research it is repeated and accentuated that diabetes is an impactful disease affecting millions of people’s everyday wellbeing and functioning of people globally. However, creating a web system to try support a huge community is neither easy nor simple. One of the most noteworthy results of this study was the awareness of the lack of communication between the medical diabetic personnel and the diabetic patients. This is mostly reported in certain areas like North America more than in the United Kingdom. This viewpoint has been helpful leading to questions in need to be answered and could be involved in this project. A completely distinct research study can be created and developed looking at different features of this problem. Even though it could prove to be a fascinating theme to explore, with a definite impact on the possible triumph of this web portal, it has shown to be too

widespread which could leave this study steering a different direction to its original purposes. During this project there were many findings discovered from the excruciating disease are as following:

Numerous of the diabetics from the consensus suggested and was onboard with the statement of diabetics can be split into two different groups:

Group 1	Group 2
This group takes into account of the diagnosis and try their hardest to tackle the disease by: Paying attention to their symptoms, maintain records, test frequently. This makes them feel they can control their health and it can change at the fate of their diet and exercise. As a group they particularly expressed some feelings of doubt and distrust to their healthcare professions including doctors. They have stated that the doctors have a lack of communication to the patients and are not sympathetic towards their treatment. A theme has been repeated and exaggerated in saying the doctors are not helpful and did not impact the diabetic patient’s health in tackling the illness instead they felt like the doctors made the situation worse. Patients from group 1 were fearful of civil liberties being revoked, including driving, as the doctor can do this if they wish. Therefore, this group did not agree with the unlimited and unrestricted access of the web portal with their records and information.	This group seems to be the people that the medical professionals are most concerned about, they are more likely the people to benefit from this system, yet it actually turns out would be the least group to actually use it. These are the patients that appear to not to deal with their disease. They are patients who use their medication or insulin intake all the time as they do not want to change their diet or daily lifestyle, diabetic in this group will probably be hospitalised or to experience major consequences for not looking after themselves, such as limb amputation.

Table 2 – The two different groups of diabetics from the survey

The two different groups of diabetics are not representative of the population as there may be patients that are a cross over of the two groups, one that may exercise regularly but have a poor diet. However as there is not much data to explain fully the anomalies that are present. In the survey data the distribution ratio of group one to group two of the table shown above were 7:13. The diabetic patients this proposed e-tool kit is targeted are those who do not actively track and record their vital readings, those who are less worried about their health, who do not understand fully their disease and how to control/limit negative impacts. These characteristics are similar to those in group two shown in Table 2. Despite the worries by diabetics (from the survey results) in the discussions of the e-toolkit potential tracking and alert function, both patients and doctors voted in favour of such a feature. The alerts would need to include an on/off feature, as doctors did not want to have to receive alerts for all their patients. The consensus indicated that this would be a very useful feature, but only for certain, high-risk patients. Additionally, the parameters that would initiate such an alert would have to be adjustable. Both groups insisted that this was essential, as ranges vary depending on the individual and on the individual’s specific set of

circumstances at a given time. For instance, a “normal” blood glucose range for one person may be drastically different from their own range two years ago or that of another person.

For the medical community, the biggest concern that would potentially prevent use of this site would be if it were not secure. Medical professionals would be professionally and ethically barred from using a site that is easily hack-able or does not take appropriate security precautions. Their second highest concern was that the site would be too complicated for patients to use correctly and because of this the data may be corrupted. The third highest stated concern was that the site would be too complex for doctors to use easily thus being too time consuming and impractical.

Important disclaimer: as was pointed out by some of the diabetic survey respondents, the people who were able to be contacted and who were willing to participate in this research were primarily (with the exception of four hospitalised patients) the type of patients who classify into group 1 (Mathieu-Fritz, Alexandre & Guillot, Caroline., 2017). These are the proactive, go-getter diabetics. The patient responses received from this group are slated towards the feelings and viewpoints of this group and do not necessarily represent a good cross-section of all diabetics. Unfortunately, this reality was pointed out afterwards and if this project were expanded further in-depth, a thorough cross-sampling of diabetic participants would most likely have to be secured with the assistance of the medical community.

A surprising two-thirds of the diabetics surveyed said that they do not find it difficult to keep track of monitoring and recording their health factors. Again, however, this information must be viewed in the context that the people responding are in the group 1. It is hoped an e-toolkit such as this will help to convert more people over from group two into group one. By making it easier and simpler for them to maintain their records and by providing them with more support in this task, from the doctor’s office.

The result of the conducted survey shows that existing monitoring systems do not support knowledge sharing and dissemination between medical staff and diabetic patients. Therefore, an e-toolkit has been suggested to overcome the issues mentioned above.

4. Final Product and Functionality

This section shows the final product that was designed and implemented to meet the above requirements.

4.1 Development and Technical Background

After a comprehensive research on the tools and techniques to be used to implement the proposed E-Tool Kit, it was concluded that it is best to use PHP to develop the front end of the e-tool kit and MySQL for the Database.

- PHP is a widely-used open source general-purpose scripting language that is especially created for web development and can be embedded into HTML. (php.net, 2018)
- MySQL (Structured Query Language) is known as “the world’s most used” relational database management system (RDBMS). It is used in many high-profile products including Wikipedia, Google, Facebook, and Twitter. MySQL is open source for private use or for products created with MySQL which, themselves, will be open source. Commercial edition licenses are available for non-open source products (MySQL, 2019)

4.1.2 Conclusion

MySQL is the best choice for this project’s purposes. In addition to being free of charge, it is easy to use, highly compatible with the chosen PHP language, and offers a wide selection of support options and resources. It also offers a sufficient amount of storage

space, has a high speed and a renowned, reliable, intuitive system. (Darwish F, 2012)

4.2 View of doctor’s page on e-toolkit



Figure 7 – View of Doctors page

4.3 View of patient’s page on e-toolkit



Figure 8 – View of Patient page

5. PRODUCT EVALUATION AND FUTURE WORK

Whilst developing this research study it became clear that the original projected objectives and features were too grand and ambitious with the limited time and resources obtainable. It is easy to get carried away with researching and developing all of the opportunities the web portal can provide and disregarding the website's fundamental main necessities and ease of use. Some of the ambitious features could have been as successful if the website was designed by an experienced team of expertise developers however this project was created by a single student and cannot obtain the same level with limited experience and time.

Upon the improvement of the web portal's appeal and flexibility that can be foreseen in the future, the section below addresses some features that can be considered in potential upcoming versions of the site.

- *Registration of multiple doctors*- If there was a feature that permitted the patients to register more than one healthcare specialist this would allow everyone having access to the same up-to-date information, allowing to input and update the records and the ability to communicate with the same channel. The healthcare specialists could include from the patient's general practitioner, dietician, dentist or the pharmacist.
- *Field importation of data* - the web portal could have fields for laboratory test results or information from the medical file inputted by the doctors. For instance, HbA1c and cholesterol readings can be projected as easily as the insulin and blood glucose readings as seen currently. It would be predominantly stored to be seen by other medical personnel.
- *Emergency alerts* - to gain the immediate attention for the doctor if a specific range has been exceeded. However, if the

alerts are not serious doctors have the option to switch this feature on and off and adjust the notification criteria.

- *Alteration of chart parameters* - trends need to be organised so visualisation of the features is crucial against a timeline or in comparison of other features.
- *Field importation for Type-1 - Patients* - this group needs to be provided with fields for readings, including insulin pump and basal and bolus insulin.

Currently in the web portal, there are some field headings like 'DIET' and 'NOTES', where all the data information has been stored although in the future, they could be additional field for specific factors from injuries, menstrual cycle, body temperature to meal calculation, medications and infections, and many more. This can prove to be very useful as this information can be tracked and used to predict trends. This list of factors was produced in the

survey comment sections suggested by the patients.

The following survey was given to evaluators to ensure that all parts of the e-toolkit were accessed and inspected:

Figure 9 – Example of survey assessing the e-toolkit

To summarise, our analysis proves that it is hard to find a relevant system that genuinely satisfies the diabetic's requirement for a solitary place where all vital data can be recorded easily and quickly. The goal for this project is to provide patients with the capacity to login and share all their fundamental data with their medical team, in an organised and effective way.

Although technology is constantly evolving, and there is an ongoing effort being made to create applications and e-Toolkits for use by the diabetic community, the evidence presented shows that it is difficult to find a system that truly fulfils the diabetic's need. Furthermore, it is virtually impossible to find any kind of system which provides the medical community with real time access to such data. This project aims to provide patients with the ability to login and share all information directly with their doctors, in a structured and efficient manner. Equally important, is the doctor's ability to provide feedback to the patient and intervene in the event of a medical complication or emergency. These features will be this e-toolkit's primary functions.

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